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October 1990

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October 1990

Prepared for
NATURAL AND CULTURAL RESOURCES DIVISION
U.S. ARMY ENGINEERING AND HOUSING SUPPORT CENTER

PREFACE

This report was prepared by Dr. Charles H. Racine, Research Biologist, Geological Sciences Branch; Ronald N. Bailey, Biologist, and Antonio J. Palazzo, Research Agronomist, Geochemical Sciences Branch, U.S. Army Cold Regions Research and Engineering Laboratory. This research was funded by the Natural and Cultural Resources Division of the U.S. Army Engineering and Housing Support Center, Ft. Belvoir, Virginia, under the direction of Donald Bandel.

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Scheduling Fall Seedings for Cold-Climate Revegetation

CHARLES H. RACINE, RONALD N. BAILEY
AND ANTONIO J. PALAZZO

INTRODUCTION

In cold climates, construction projects are frequently completed in the fall. A decision must then be made concerning the seeding schedule for revegetating disturbed areas. The timing may be crucial for the successful establishment of grasses and legumes for soil erosion control. There are four scenarios for fall-seeded species (Fig. 1), and they depend on the time of seeding:

1) Germination in the fall and overwintering as an established seedling, followed by the resumption of growth in the spring (referred to here as "permanent seeding");
2) Fall germination but high rates of seedling mortality, or winterkill;
3) No germination until the following spring or summer (referred to here as "dormant seeding"); and
4) A mix of 2 and 3 or 1 and 2.

Figure 1 shows that there is a one- to two-month transition period between the latest date for permanent seeding and the earliest date for dormant seeding. If seeding occurs between these dates, there is presumably an increased risk of seedling mortality due to low fall and winter temperatures. Depending on the date of project completion and the site, permanent or dormant seedings are more desirable than seeding within the transition period.

The pathway that fall seeding takes depends on the date of seeding, which directly relates to soil surface temperatures (or the heat sums remaining in the growing season) compared to what is required by the species sown. Growing degree-days (GDDs) can be used to express heat sums by subtracting a minimum (or maximum) temperature threshold from the average daily temperature and accumulating these values. The growth and development of most crop plants have been closely correlated with air or soil thermal units, heat sums or growing degree-days (Klepper et al. 1988). However, cool-season turf and forage grass requirements are poorly known.

In addition, mulches or soil covers may alter the surface soil temperatures (Bristow 1988) and therefore alter daily heat sums so that the timing of seed germination and establishment change. Soil moisture and light have been reported to be less significant factors in plant establishment during the northern fall (Gartner 1983). In the case of dormant seeding, spring temperatures and moisture conditions are also important when the growing season begins again.

Fall seeding and mulching are in some ways analogous to the natural cycle of seed ripening and dispersal and leaf litter production that occurs in most temperate ecosystems. However, in nature, most seeds produced by cold-climate species in the fall remain dormant until the following growing season (Gartner 1983). Germination is prevented by enforced dormancy (low temperatures, shortage of moisture, etc.) rather than by an intrinsic dormancy mechanism. Fall leaf litter cover in natural systems (analogous to mulches) may further reduce light and temperatures conditions, encouraging dormancy (Thompson and Grime 1979). Spring germination usually occurs at temperatures of 5–10°C in northern species (Gartner 1983).

Figure 1 is based on seeding schedules from Johnson (1981) and Hardy BBT Ltd.(1987) for Alaska and Canada and on our studies in New Hampshire (Palazzo 1989). These schedules are based on experience rather than on an analysis of seed germination and establishment in relation to fall and spring temperatures.

There is clearly a need to develop a less "hit or miss" technique for scheduling fall seedings for a particular site. The purpose of this study is to develop a more precise technique for predicting and scheduling fall seeding and mulching with various materials using calculations of growing degree-days.

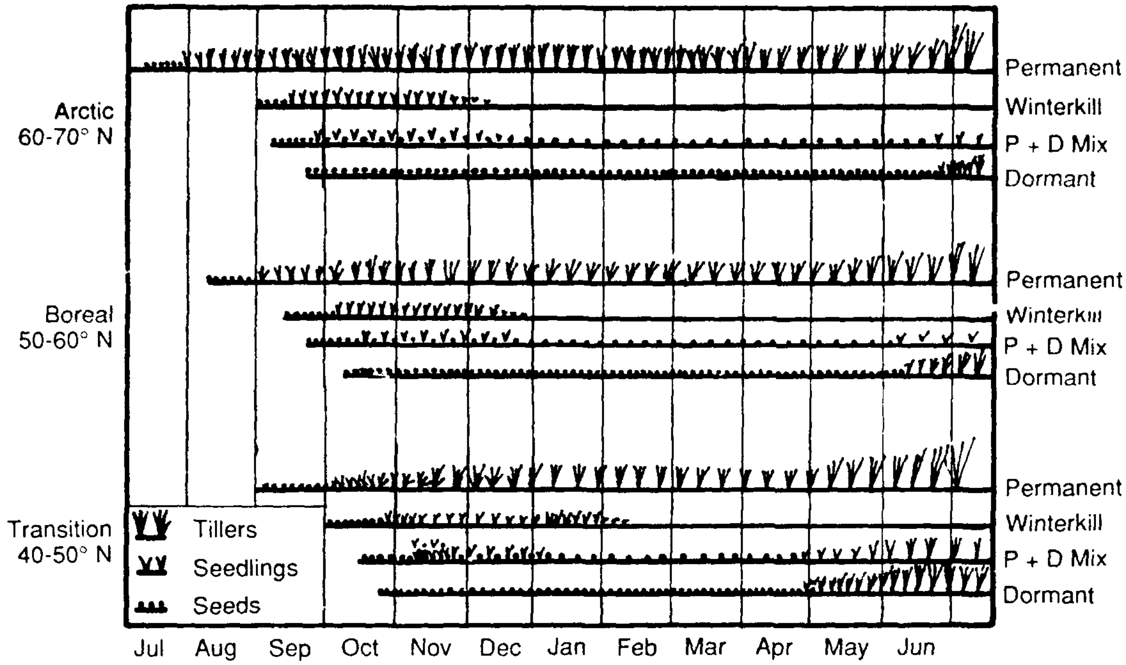

Figure 1. Hypothetical scenarios describing the outcome of seeding cool-season grasses at four dates during the fall at different northern latitudes (compiled from Johnson 1981, Hardy BBT Ltd. 1987 and Palazzo 1989).

METHODS

Two related outdoor experiments were conducted in Hanover, New Hampshire (latitude 45°N), during the falls of 1988 and 1989. On 1 September and 23 October 1988, 1000 seeds of Mustang tall fescue (*Festuca arundinacea* Schreb.) were sown into 1- × 1-m plots on a west-facing slope. Two covers (and an uncovered control) were used to alter soil surface temperature, moisture, etc. The covers included a straw erosion blanket (2 tons/acre) and Typar, a row cover used to increase temperatures in the spring and fall (Wells and Loy 1985). The plots were randomly arranged in a row and replicated three times each for a total of nine plots. Thermocouples placed on the soil surface in the center of each plot were attached to a datalogger (Omnidata, Logan, Utah). Soil surface temperatures (beneath the covers) were monitored hourly, averaged and recorded on a six-hour basis. We calculated daily growing degree-days by summing the difference between the six-hour average temperature and 5°C and dividing by four. Seed germination, seedling growth and seedling survival were monitored in these plots during the fall and into the following spring and summer.

A second field study was conducted in the fall of 1989. Prior to plot establishment, the vegetation in a level 10- × 20-m plot was killed with an herbicide (Roundup), and 25 holes (30 cm in diameter by 50 cm deep) were dug 1 m apart in a checkerboard design. Plastic pots (25 × 25 cm) were placed in these holes, and sand was packed around the sides so that only the rim of each pot was above the ground. These pots were filled with a mixture of potting soil, peat moss and perlite in equal proportions. At one-week intervals beginning on 5 October and ending on 2 November, 100 tall fescue seeds were planted into each of eight randomly selected pots. After each seeding four of the eight pots were covered with the row cover (Typar) so that each treatment (time of seeding and cover) was replicated four times. Seed germination, leaf development and temperatures were monitored in each pot.

RESULTS

Fall decline in remaining growing degree-days

The number of growing degree-days at the soil surface declines rapidly in the fall. We plotted the number of soil surface growing degree-days remaining in the growing season after each one week interval beginning on 5 October 1988 for straw mulch, Typar and control plots (Fig. 2). In the uncovered and straw-mulched plots on 1 September 1988, there were about 500 GDDs re-

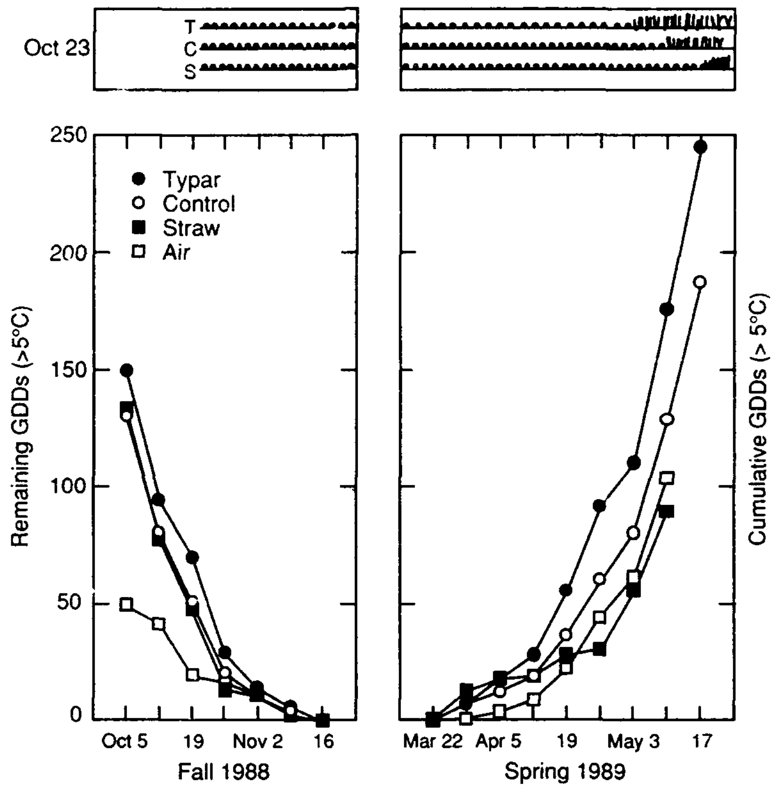

Figure 2. Soil surface and air growing degree-days remaining at various dates during the fall of 1988 and accumulated during the spring of 1989 under straw, Typar and control on a west-facing slope in Hanover, New Hampshire. Degree-days were calculated using 5°C as a low-temperature threshold. Also shown is the timing of spring germination in 23 October seedings under Typar, straw and control.

maining in the growing season. By 1 October, only 140 GDDs on the slopes and 190 GDDs in the pots remained. Typar added about 20–30 GDDs to the amount remaining on 5 October and 15–20 to the amount remaining on 15 October.

Growing degree-day values based on air temperature data from the U.S. Weather Bureau station in Hanover, New Hampshire, were also calculated for comparison with the soil surface temperature data (Fig. 2). The shapes of these curves are similar to those for the soil surface temperatures but were generally lower by 25–50 degree-days because of the greater thermal stability of soil vs air.

Spring growing degree-day accumulation

In Hanover the rapid buildup of soil surface growing degree-days began in late March, reaching 150 GDDs by 1 May in the flat plot (Fig. 2 and 3). In contrast with the fall, there were strong differences in the accumulation of GDDs between the various straw-mulched plots and the control plots.

Seed germination and seedling growth

Seeding on 1 September in the 1- × 1-m plots resulted in the establishment of a permanent stand of tall fescue, while seeding on 23 October resulted in no germination until the following spring (Fig. 2). A 15 October seeding of tall fescue resulted in permanent establishment under Typar and mixed (both germination and dormant) in the control plot without a cover. Most of the seedlings in this control plot died during the winter.

In the dormant plots (seeded on 23 October), spring tall fescue germination began about 1 May in the plots covered with Typar. This corresponds to the accumulation of about 120 GDDs at the soil surface (Fig. 2). At this time there was no germination in the straw-covered

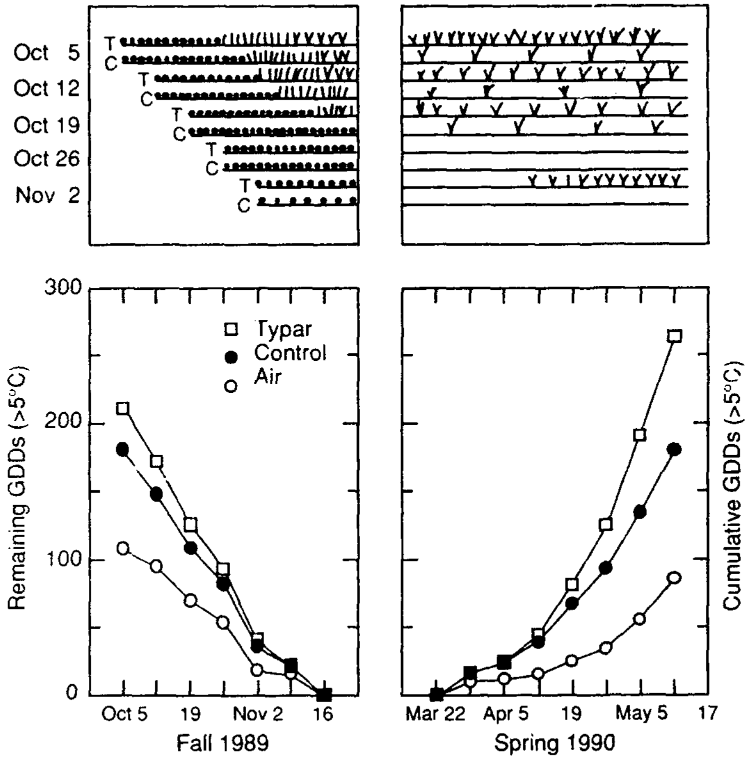

Figure 3. Soil surface and air growing degree-days remaining in the fall of 1989 and accumulated in the spring of 1990 in Typar-covered and uncovered buried pots. Degree-days were calculated using 5°C as a low-temperature threshold. Also shown is the behavior of tall fescue seeds sown at one-week intervals.

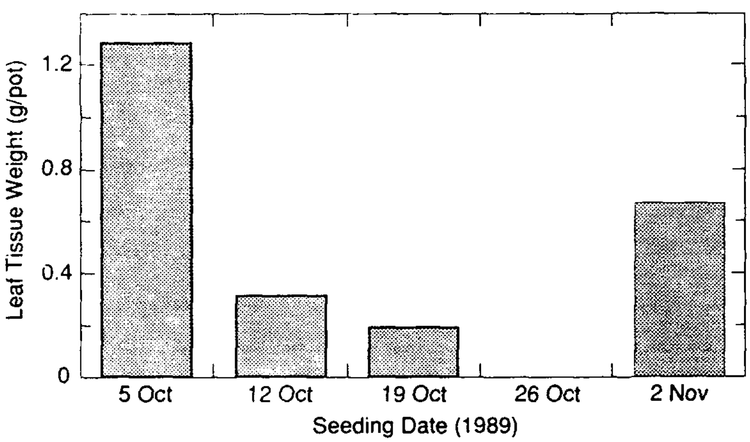

Figure 4. Average dry weight per pot on 1 June, 1990, of above-ground tall fescue tissue in Typar-covered pots seeded at five dates during the fall of 1989.

plots, which did not have comparable germination until 15 May. The uncovered control plots showed slightly later (5 May) germination than the Typar-covered plots. Large populations of weeds (*Oxalis* sp.) germinated during this same period in all plots and eventually replaced the grass seedlings. Harvests of these plots in July 1989 indicated that tall fescue yields were over four times higher in the 1 September permanent seedings than in the 23 October dormant seedings.

Of the five pot seedings at one-week intervals, only the first (5 October) and second (12 October) reached at least 50% germination in both the control and Typar-covered pots by the end of the growing season in mid-November (Fig. 3). Of the eight pots seeded on 19 October, only the four Typar-covered pots reached 50% germination. Germination of the tall fescue therefore required about 100–150 growing degree-days, or 16–20 days under the Typar and 22–30 days without the Typar.

A second leaf developed on at least 50% of the seedlings from seedings made on 5 October, both with and without Typar. The 12 October seeding under Typar also developed seedlings with two leaves before the end of the growing season. Therefore, once germinated, development of a second leaf required an additional

50–75 GDDs, or 10–18 days. Seeds sown on 5 October without Typar reached the second leaf stage at about the same time as those sown a week later (12 October) with Typar.

Harvest of these fall-seeded pots in the spring (1 June) showed little or no survival without a Typar cover. In the Typar-covered pots the yield was highest in the earliest seeding (5 October) and in the latest dormant seeding (2 November) (Fig. 4). The 26 October seeding failed to produce any seedlings in the spring.

DISCUSSION AND CONCLUSIONS

By calculating the number of growing degree-days remaining in the growing season for various fall seeding dates, it is easier to predict the success of fall seedings. The date necessary to produce a dormant seeding and avoid late-fall germination and winterkill can also be calculated more precisely. Curves of the remaining growing degree-days at the soil surface in Hanover (Fig. 3) can be approximated with a power function of the form

$$\text{Julian date} = 360 \times (\text{GDDs})^{-0.05}.$$

If the heat sum requirement (expressed as GDDs) for the various developmental stages of a particular species is known, then the date on which seeding must take place in Hanover to obtain germination or reach various leaf or tillering stages can be calculated. If dormant seeding is desired, then seeding should occur after the date on which the 100 GDDs necessary for germination remain in the growing season. Using the equation above for Hanover yields day 283 (10 October). To obtain established tall fescue seedlings with a combined germination and second leaf requirement of 175 GDDs, a seeding date of day 278 (5 October) was obtained.

We do not know the optimum seedling age or growth stage for cold tolerance of tall fescue. However, Arakeri and Schmid (1949) found that young grass seedlings are very susceptible to low temperatures. Kellner et al. (1978) showed that in Italian ryegrass (*Lolium multiflorum*) cultivars the highest rate of tiller survival during freezing temperatures was at seedling ages between 58 and 68 days.

Since it is not always practical or possible to obtain soil surface growing degree-days for a particular location, published U.S. Weather Bureau daily maximum and minimum air temperatures can be used to calculate a GDD curve. Because of soil surface radiant heating, the actual number of growing degree-days available at the soil surface in the fall is usually 10–20% higher than the air temperature GDD curve. Therefore, a lower air temperature GDD requirement for germination and leaf development should be used. For example, Figure 5 shows the fall decline in growing degree-days using 1986 air temperature data from Fairbanks, Alaska. The new power curve equation for remaining GDDs using this Fairbanks air temperature record is

$$\text{Julian date} = 300 \times (\text{GDDs})^{-0.05}.$$

Using this equation, dormant seeding could be achieved by seeding after 1 September.

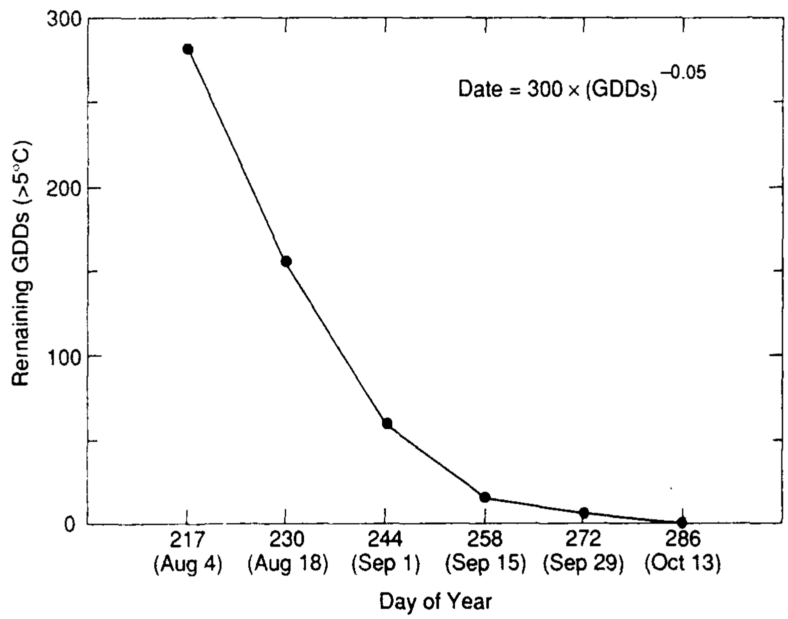

Figure 5. Fall growing degree-day curve for Fairbanks, Alaska, constructed from U.S. Weather Bureau data (daily maximum and minimum air temperatures) from 1986.

Dormant seedings are encouraged in arid areas where the major source of soil moisture is early spring snowmelt. Some regions of Alaska fall into this category, and dormant seeding was used in the construction of the oil pipeline (Johnson 1981). Disadvantages of dormant seeding include the loss of seeds to erosion on slopes or predation by seed-eating birds or other animals. In Hanover, our dormant-seeded plots sometimes showed poor yields due to the large numbers of weed seeds that germinated in the spring ahead of the seeded species. This problem was exaggerated under the Typar row cover.

While mulches used during the fall did not appear to change the growing degree-day relationships and therefore the seeding dates, certain mulches may delay germination of dormant seedings by as much as two weeks in the spring. By this time in some areas, the soil moisture provided by snowmelt may no longer be available.

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Revegetating construction sites in the fall requires the scheduling of seeding and mulching for either permanent or dormant seedings. Dormant seedings must be late enough in the fall to prevent germination, while permanent seedings must be early enough to permit seedling establishment and avoid winterkill. A technique for determining optimum seeding dates using growing degree-day curves was developed and tested. Small outdoor plots and buried pots in Hanover, New Hampshire, were seeded with tall fescue at intervals during October 1988 and 1989, respectively, and covered with either straw mulch or a Typar row cover. Soil surface temperatures, germination and growth were monitored into the following spring. Fall or spring germination of fall-sown tall fescue seeds required about 100 GDDs (over 5°C), while the development of a second leaf required an additional 70 GDDs. In the experimental plots without any cover, these requirements were met with 12 October and 5 October seedings, respectively; with a Typar cover, seeding dates could be delayed by one week. In pots the greatest spring yields were obtained under Typar at the earliest (5 October) seeding date and the latest dormant seeding date (2 November). Straw mulch applied during the fall had little or no effect on the number of growing degree-days remaining. However, during the following spring, it slowed soil warming and germination of dormant seedings. The appropriate fall seeding date for northern areas can be calculated using a power curve for Hanover, New Hampshire: Julian date = 360 × (GDDs required)$^{-0.05}$. Keywords: *Seeds, *Fertilization, *Vegetation. (2 the [illegible] to the minus 0.05 power)

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